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LASER BEAM SHAPING OF ELEMENTS OF SLIDING FRICTION SUPPORTS

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by

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13. ABSTRACT

This article presents results involving the application of lasers for the production of sliding friction supports used in instrument building; typical support designs are shown. Furthermore, regression equations are concluded for elements of typical sliding friction supports considering the primary factors influencing their design dimensions. The use of lasers can allow the production of an aperture or depression directly in a load bearing plate similar in shape and size to stone bearings in a single generating pulse, and also allows the formation of ends with various design characteristics on axes, while simultaneously hardening the material in the treatment zone. This allows expensive stone bearings and supports to be eliminated, producing support elements in a single generation pulse with simple later finishing.
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Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

LASER BEAM SHAPING OF ELEMENTS OF SLIDING FRICTION SUPPORTS

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Given in the article are the results of using lasers to get sliding friction supports used in instrument construction; shown are standard designs of supports.

In addition regression equations are derived for elements of standard sliding friction supports, which take into account the main factors that affect their design dimensions.

In varicus areas of instrument manufacture one of the technological problems is obtaining elements of sliding friction supports. At present in a majority of cases these supports are assembled, using stones as bearings and step bearings, and as journals materials with improved physicomechanical characteristics (see table, position A-1 to A-5)[1].

The development of lasers lets us take another look at the given solution both from the point of design of supports and from the position of the technology of their production. This is due to the fact that some problems can be solved using lasers:

— obtaining, in one generation pulse, holes or depressions directly in the carrier plate which in form and size are close to stone bearings (table, position B-3 to B-5);

— developing of a journal on axes with various design characteristics (see table, position B-1 to B-2);

— simplifying of materials in the processing zone.

In this case a possibility opens up with respect to creation of elements of supports directly in plates and axles with their simultaneous shaping and simplification of material to the assigned value.

Such design-technological solution allows:

— excluding from construction expensive stone bearings and step bearings,

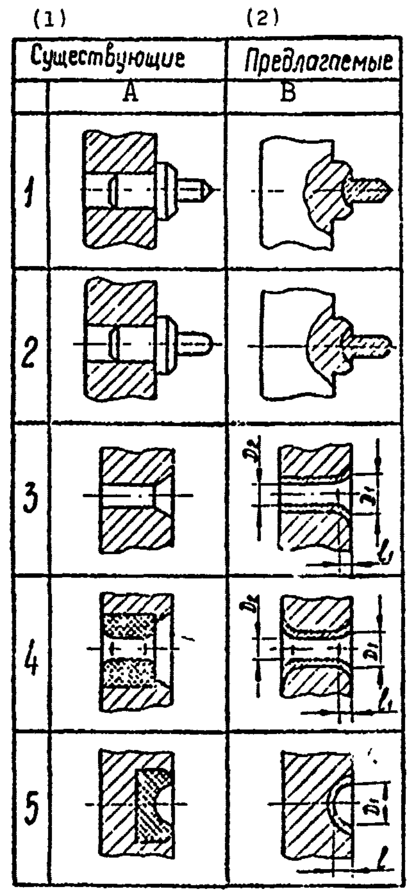
— obtaining billets of elements of supports in one generation pulse with subsequent finishing work low in terms of labor;

— excluding operations with respect to assembly and regulation of stone supports, which cannot but be reflected on the main production criteria, such as economy, labor consumption, and productivity.

In this connection the study of the given question deserves some attention from the point of view of elucidating the mechanism of shaping of elements of supports, technological possibilities of this method, and process control.

As investigations have shown, the mechanism of shaping of elements under step bearings and bearings at the present time is clear enough and is the usual process with respect to formation of depressions and holes of assigned form-size [2, 4].

Main constructions of elements of sliding friction supports.



KEY: (1) Existing; (2) Proposed.

The mechanism of shaping of billets under journals is connected with rather complex phenomena, little investigated at the present time.

With the interaction of a light beam with material at energy densities considerably lower than with the obtaining of elements of bearings, it is possible to create conditions in which the metal in the zone of radiation will be mainly in the liquid state. During the action of hydrodynamic phenomena developed in this case in the zone of interaction, the molten metal undergoes considerable deformation, as a result of which its swelling occurs in the center

of action of the light ray. In view of the low energy density the given form (form of "bead") is kept after the completion of the process, forming in this case a billet under the journal.

The main technological factors having a substantial effect upon the process of shaping of the given elements are the radiation energy of the laser W_Σ, the position of the focus of the control lens relative to the surface being worked ΔF,[1] the focal length of the lense F, the duration of the radiation τ, and the thermophysical characteristics of the material being worked T.

The given technological characteristics can be connected with the geometric parameters of elements of supports using regression equations. For example, the regression equations for the internal diameter of the bearing D_2, depth l, size of bearing chamber D_1 and l_1 (see table) have the following form:

$$\begin{aligned}D_2 = \{[(a_{1_{D_2}}T + b_{1_{D_2}})F + a_{2_{D_2}}T + b_{2_{D_2}}]\,\Delta F^2 + [(a_{3_{D_2}}T +{} \\ b_{3_{D_2}})F + a_{4_{D_2}}T + b_{4_{D_2}}]\,\Delta F + [(a_{5_{D_2}}T + b_{5_{D_2}})F + a_{6_{D_2}}T + b_{6_{D_2}}]\}\,W_\Sigma +{} \\ + [(a_{7_{D_2}}T + b_{7_{D_2}})F + a_{8_{D_2}}T + b_{8_{D_2}}]\,\Delta F^2 + [(a_{9_{D_2}}T + b_{9_{D_2}})F +{} \\ + a_{10_{D_2}}T + b_{10_{D_2}}]\,\Delta F + (a_{11_{D_2}}T + b_{11_{D_2}})F + a_{12_{D_2}}T + b_{12_{D_2}} \ldots\end{aligned} \qquad (1)$$

$$\begin{aligned}l = \{[(a_{1_l}T + b_{1_l})F + a_{2_l}T + b_{2_l}]\,\Delta F^2 + [(a_{3_l}T + b_{3_l})F +{} \\ + a_{4_l}T + b_{4_l})\,\Delta F + [(a_{5_l}T + b_{5_l})F + a_{6_l}T + b_{6_l}]\}\,W_\Sigma +{} \\ + [(a_{7_l}T + b_{7_l})F + a_{8_l}T + b_{8_l}]\,\Delta F^2 + [(a_{9_l}T + b_{9_l})F +{} \\ + a_{10_l}T + b_{10_l}]\,\Delta F + (a_{11_l}T + b_{11_l})F + a_{12_l}T + b_{12_l} \ldots\end{aligned} \qquad (2)$$

$$\begin{aligned}l_1 = \{[a_{1_{l_1}}T + b_{1_{l_1}}) + (a_{2_{l_1}}T + b_{2_{l_1}})\,\Delta F + (a_{3_{l_1}}T + b_{3_{l_1}})\,e^{\Delta F}]\,F +{} \\ + (a_{4_{l_1}}T + b_{4_{l_1}}) + (a_{5_{l_1}}T + b_{5_{l_1}})\,\Delta F + (a_{6_{l_1}}T + b_{6_{l_1}})\,e^{\Delta F}]\,W_\Sigma +{} \\ + [(a_{7_{l_1}}T + b_{7_{l_1}}) + (a_{8_{l_1}}T + b_{8_{l_1}})\,\Delta F + (a_{9_{l_1}}T + b_{9_{l_1}})\,e^{\Delta F}]\,F +{} \\ + (a_{10_{l_1}}T + b_{10_{l_1}}) + (a_{11_{l_1}}T + b_{11_{l_1}})\,\Delta F + (a_{12_{l_1}}T + b_{12_{l_1}})\,e^{\Delta F} \ldots\end{aligned} \qquad (3)$$

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[1]The focus relative to the surface being worked can be in one of three positions: on the surface of the billet $\Delta F = 0$, inside $- \Delta F > 0$, and above the surface $- \Delta F < 0$.

$$D_1 = \{[(a_{1_{D_1}}T + b_{1_{D_1}})F + a_{2_{D_1}}T + b_{2_{D_1}}]\,\Delta F^2 + [(a_{3_{D_1}}T + b_{3_{D_1}})F + \\ + a_{4_{D_1}}T + b_{4_{D_1}}]\,\Delta F + (a_{5_{D_1}}T + b_{5_{D_1}})F + a_{6_{D_1}}T + b_{6_{D_1}}]\,W_\Sigma + \\ + [(a_{7_{D_1}}T + b_{7_{D_1}})F + (a_{8_{D_1}}T + b_{8_{D_1}})]\,\Delta F^2 + [(a_{9_{D_1}}T + b_{9_{D_1}})F + \\ + a_{10_{D_1}}T + b_{10_{D_1}}]\,\Delta F + (a_{11_{D_1}}T + b_{11_{D_1}})F + a_{12_{D_1}}T + b_{12_{D_1}} \ldots, \quad (4)$$

where a_{i_D}; b_{i_D}; a_{i_l}; b_{i_l} are coefficients with independent variables, the numerical values of which can be determined, by using a computer.

Depending upon conditions of treatment, the accuracy of dimensions of bearings and step bearings corresponds in a majority of cases to 2-3rd class with a surface purity of 7-8th class. In this case the total assigned profile is in many respects caused by use of additional calibrating means: gas jets, reverse action of light ray, etc., [2], [3].

Optimal conditions of laser treatment, depending upon the geometric parameters of the bearings, can be selected on the basis of solution of regression equations 1-4.

The billets under the journals are formed with a precision of 4-5th class and require supplemental finishing operations.

As follows from analysis of experimental data, and also of equations (1)-(4), one of the main factors that affects the shaping of one element of support or another is the position of the focus of the control lens relative to the surface being worked. When $\Delta F = 0$ bearings are formed which are presented in the table on positions B-3, B-4 (W_Σ = 120 joules, F = 50 mm, $\tau = 1.5 \times 10^{-3}$ s, the material being worked is steel 30KhGSA); when ΔF = -5 to -8 mm a step bearing is formed, the form and size of which is given on position B-5, and with a 6-9 mm shift of focus in the positive direction, a billet is formed under the journal, positions B-1, B-2.

The third problem connected with hardening material and giving it certain physicomechanical characteristics is reached simultaneously with the process of shaping of elements of supports.

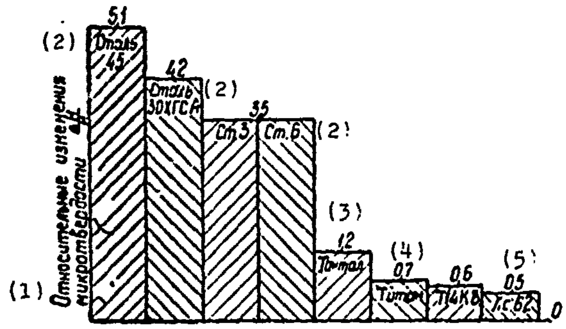

Fig. 1. Relative change of microhardness of various materials. KEY: (1) Relative changes of microhardness; (2) Steel; (3) Tantalum; (4) Titanium; (5) Ls-62.

It is known that for a majority of materials under the action of laser radiation changes occur in the limits of the zone of radiation[1] of the structure of the material and its mechanical properties. In this case the microhardness of the material increases, and a compressed finely divided structure is formed [2].

The size of the zone of structural changes A and the increment in the hardness of the material in comparison with the original hardness (ΔH) is a function of those same technological factors that affected the process of shaping elements of supports, i.e.,

$$A,\ \Delta H = f(W_{\Sigma};\ F;\ t;\ \Delta F;\ T).$$

Experiments run with the whole group of materials showed that when W_{Σ} = 120 joules, F = 50 mm, and ΔF = 0, the microhardness of steel 45 increases five times in comparison with the original material, that of steel 30KhGSA – four times; that of steel 3 – 3.5 times, that of brass LS-62 stays practically the same, Fig. 1.

[1]The zone of radiation is the region of action of the light ray in the limits of which occurs not only removal of material, but also its structural changes.

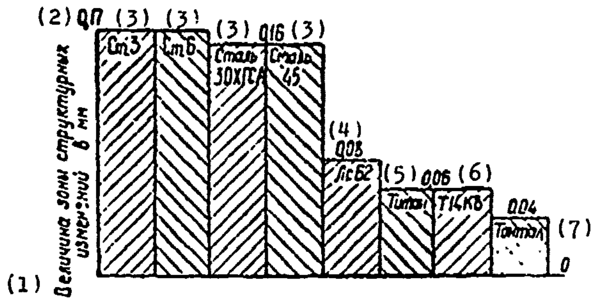

Fig. 2. Width of zone of structural changes.
KEY: (1) Value of zone of structural changes in mm; (2) Unknown; (3) Steel; (4) Ls-62; (5) Titanium; (6) T14Kd; (7) Tantalum.

The zone of structural changes of steel billets is a white nonetching layer the value of which during the piercing of holes is in the limits 0.16-0.17 mm; for brasses and solid alloys it corresponds to 0.06-0.08 mm, Fig. 2. The value of the given zone is entirely sufficient for hardening the walls of the hole and giving the bearing or step bearing certain properties.

In the shaping of journals the latter are completely formed from material subjected to physicomechanical changes under the action of laser radiation (see table, positions B-1 and B-2). The checking of the given elements for wear showed their high resistance to wear.

Thus using lasers in instrument making technology for the production of elements of slip bearings opens a new, very promising technological trend.

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